JAPANESE / ENGLISH TRANSLATION OF

Japanese Patent Application JP 3 - 121135 A

Resinous Sliding Element

Your Ref.: 20030260

For W.L. Gore & Associates, Inc.

9109 Eagle Hills Dr . Las Vegas NV 89134 . ph: 866-722-7990 (toll-free) . fax: 702-973-6009 . email: sales@tls-translations.com

(19) Japanese Patent Office (JP)

(11) Unexamined Patent Application (Kokai) No.

(12) Unexamined Patent Gazette (A)

3–121135

(51) Int. Cl.^{5}		Classification Symbols		Internal Office Registration Nos.
C 08 J	5/14			8517–4F
C 08 L	27/12	LGL		7445–4J
C 10 M	107/38			8217–4H
F 16 C	33/20		Z	6814–3J
// C 10 N	40:02			
	50:08			

(43) Date of Publication: May 23, 1991

Request for Examination: Not yet submitted Number of Claims: 1 Total of 11 pages [in original]

(54) Title of the Invention: Resinous Sliding Element

(21) Application No.: 1-259093

(22) Date of Filing: October 4, 1989

(72) Inventor: Kiyoshi Kato (c/o Toyota Central R&D Labs., Inc., 41-1, Aza Yokomichi, Oaza Nagakute, Nagakute-cho, Aichi-gun, Aichi-ken)

(72) Inventor: Yoshio Shimura (c/o Toyota Central R&D Labs., Inc., 41-1, Aza Yokomichi, Oaza Nagakute, Nagakute-cho, Aichi-gun, Aichi-ken)

(72) Inventor: Yoshiyuki Mizutani (c/o Toyota Central R&D Labs., Inc., 41-1, Aza Yokomichi, Oaza Nagakute, Nagakute-cho, Aichi-gun, Aichi-ken)

(71) Applicant: Toyota Central R&D Labs, Inc.
41-1, Aza Yokomichi, Oaza Nagakute, Nagakute-cho, Aichi-gun, Aichi-ken

(74) Agent: Hiroshi Okawa, Patent Attorney

SPECIFICATION

1. Title of the Invention

Resinous Sliding Element

2. Claims

(1) A resinous sliding element characterized by comprising a resin-containing matrix; and an embedded fluororesin material exposed in the form of rods or a mesh in the sliding surface of the matrix and embedded in an area ratio of 5 to 40% in relation to the sliding surface.

3. Detailed Description of the Invention

(Field of Industrial Utilization)

The present invention relates to a resinous sliding element that can be used as a sliding part requiring low friction and abrasion resistance under high-load conditions, specifically under conditions of a high PV value (surface pressure (P) × slipping velocity (V)); for example a resinous sliding element that can be utilized in axle bearings, mechanical seals, and the like.

(Prior Art)

Resinous sliding elements comprising a resin matrix and fluororesin powder or fiber, or molybdenum disulfide or a graphite solid lubricant, are known in conventional practice. Such conventional resinous sliding elements are formed by dispersing and mixing fluororesin powder or the like in a matrix to improve the sliding properties of the resin matrix.

(Problems That the Invention Is Intended to Solve)

However, the above-mentioned resinous sliding elements have been insufficient in terms of low friction and abrasion resistance under high-load conditions.

The present invention was designed in view of the above-mentioned conventional problems, and an object thereof is to provide a resinous sliding element with excellent low friction and abrasion resistance even under high-load conditions.

(Means Used to Solve the Above-Mentioned Problems)

The resinous sliding element of the present invention is characterized by comprising a resin-containing matrix and an embedded fluororesin material exposed in the form of rods or a mesh in the sliding surface of the matrix and embedded in an area ratio of 5 to 40% in relation to the sliding surface.

The matrix may be a resin alone, or may also be a composite material consisting of glass fiber, carbon fiber, aramid fiber, or other such reinforcing materials dispersed in a resin. It is also common in conventional practice to disperse glass fiber in a resin to prevent the tendency of mechanical strength to decrease under high-load conditions. However, conventional resinous

sliding elements dispersed with glass fiber tend to damage other materials. Therefore, the resinous sliding element of the present invention does not easily damage other materials even when its mechanical strength is improved by glass fiber or the like.

In the present invention, graphite or another such additive for improving thermal conductivity can also be dispersed in the matrix.

A thermoplastic or thermosetting resin (engineering plastic or super engineering plastic) can be employed as the resin. The thermoplastic resin may be nylon 6, nylon 66, or another such polyamide resin; Delrin (registered trademark), Duracon (registered trademark), or another such polyacetal resin; polyethylene terephthalate, polybutylene terephthalate, or another such polyester resin; an ABS (acrylonitrile-butadiene-styrene) resin or other such engineering plastic; or polyethylene sulfide, polyether imide, polyoxybenzoyl, polyamide imide, polyether ether ketone, or other such super engineering plastic. The thermosetting resin may be a phenol-based resin (phenol resin, phenol aralkyl resin, or the like), a polyimide-based resin, or the like. This resin preferably has a surface hardness of M60 or greater on the Rockwell hardness scale. The present invention has few merits with a matrix having a Rockwell hardness of less than M60. A resin with a Rockwell hardness of M80 or greater is even more preferable.

The embedded material is a bulk material consisting of melted and fluidized PTFE (polytetrafluoroethylene) or another such fluororesin that has been cooled, and is formed so as to be exposed in the form of rods or a mesh in the sliding surface of the matrix. The embedded material may be formed into rods or a mesh by molding or the like, or may be formed into rods by being cut out of a fluororesin plate. A reticulated embedded material can be obtained by weaving rods together. Squares, diamonds, triangles, or other shapes with arbitrary intervals can be employed for the mesh configuration. The cross-sectional surface of the embedded material may be either a circle or a square.

The embedded material is embedded in an area ratio of 5 to 40% in relation to the sliding surface of the matrix. When the area ratio is less than 5%, the resin contained in the matrix is susceptible to abrasion under high-load conditions, and therefore the friction coefficient of the resinous sliding element increases. When the area ratio is greater than 40%, the embedded material in the resinous sliding element is susceptible to abrasion under high-load conditions, and therefore friction on the embedded material increases, raising costs. An area ratio of 10 to 30% is more preferable considering the performance and costs.

The thickness of the embedded material can be determined by the relationship between the area ratio and the area of the mating surface. However, an embedded material with a thickness of less than 0.1 mm resembles a fiber and makes it impossible to satisfy the mechanical strength and low friction of the resinous sliding element under high-load conditions. When the embedded material has a thickness greater than 2 mm, the embedded material in the resinous sliding element is susceptible to abrasion under high-load conditions, which raises costs. A thickness of 0.5 to 1 (mm) is even more preferable considering the performance and costs.

In order to improve consistency with the matrix resin, the embedded material is preferably subjected to surface treatment in advance by common liquid treatment methods, corona discharge, or the like.

The resinous sliding element of the present invention can be manufactured as follows. When a thermoplastic resin is used as the matrix, a green compact of the thermoplastic resin or a bulk thermoplastic resin is heated at a specific temperature, and the embedded material is pressed into the resulting product at a specific pressure. When a thermosetting resin is used as the matrix, a green compact of the thermosetting resin or a gelled thermosetting resin is heated at a specific temperature, and the embedded material is pressed into the resulting product at a specific pressure.

(Operation of the Invention)

A fluororesin has a folded crystal structure, whose excellent lubrication is said to be due to the fact that the folded structure is worn off in slices during sliding, and the resulting thin film is transferred to the mating surface. In the resinous sliding element of the present invention, the fluororesin is continually present in large amounts on the sliding surface rather than being dispersed in a powder form or fiber form, and it is therefore believed that the thin film is more easily transferred to the mating surface. The fluororesin disposed and embedded in the form of rods or a mesh, as in the resinous sliding element of the present invention, is integrated with the matrix and is not easily separated from the matrix even by sliding, but a fluororesin dispersed in a powder or fiber form is believed to be easily separated from the matrix by a sliding process. Furthermore, since the embedded material in the resinous sliding element of the present invention is in bulk form, it is believed to have many more stable crystals in its structure than does a material in powder form or fiber form. Therefore, it is suggested that in the resinous

sliding element of the present invention, the fluororesin withstands high surface pressure under high-load conditions more easily than when dispersed in powder form or fiber form, and the matrix diffuses surface pressure more easily than when composed of fluororesin alone. Therefore, it appears that the resinous sliding element of the present invention is not susceptible to abrasion under high-load conditions and has low friction.

In the case of a matrix whose mechanical strength has been reinforced by glass fiber or another such reinforcing material, it is believed that the surface pressure that the matrix can diffuse increases. If a matrix is employed whose thermal conductivity has been increased by the addition of graphite or the like, it is suggested that the difference in thermal resin ratios between the matrix and embedded material increases, which makes it easier for the embedded material to come into contact with the mating material. Therefore, it appears to be possible in such cases to obtain a resinous sliding element that can be more effectively employed under high-load conditions.

(Working Examples)

Experiments conducted using working examples and comparative examples are described below with reference to diagrams and tables. The Rockwell hardness of the resin used as the matrix is approximately as follows on an M-scale. Nylon 6: 60, nylon 66: 80, polyoxymethylene (Delrin): 90, polyoxybenzoyl: 70, polyether ether ketone: 100, polyamide imide: 130, polyimide: 90-100, phenol aralkyl resin: 90-100, rubber-modified phenol resin: 80.

(Experiment 1)

The manner in which sliding properties were affected by high PV values was tested by embedding a material into the surfaces of common thermoplastic resins and thermosetting resins. The nylon, polyoxymethylene, and the like shown as the matrix in Table 1 are sometimes used as common sliding elements, but the other resins are not necessarily used as sliding elements.

First, a box-shaped reticulated embedded material with a thickness of 1 (mm) and intervals of 2 to 3 (mm) was prepared by molding a melted and fluidized PTFE. This embedded material had an area ratio of about 40% in relation to the sliding surface of the matrix. The embedded material was then subjected to surface treatment by common liquid treatment methods using a surface-treating agent to improve adhesiveness between the matrix resin and the PTFE.

For Working Example 1, the matrix, a plate of nylon 66, was heated to 260(°C), and the above-mentioned embedded material was pressed into the resulting product at 200 (kg/cm^2). After cooling, the surface was polished to form a flush surface, yielding a resinous sliding element. As shown in the perspective view of Fig. 1 and the enlarged cross-sectional view of Fig. 2, this resinous sliding element comprised a matrix 1 composed of nylon 66, and an embedded material 2 that was embedded while exposed as a mesh in the sliding surface of the matrix 1.

For Comparative Example 1, a resinous sliding element was prepared using nylon 66 without the above-mentioned embedded material.

For Working Example 2, a resinous sliding element was prepared by the same method as in Working Example 1 using a plate-shaped matrix comprising 70 wt% of nylon 66 and 30 wt% of glass fiber with a thickness of 10 (μm).

For Comparative Example 2, a resinous sliding element was prepared comprising nylon 66 and glass fiber without the above-mentioned embedded material.

Similarly, as shown in Table 1, the resinous sliding elements in Working Examples 3-11 and Comparative Examples 3-11 were obtained with varying matrices. Thus, the resinous sliding elements in Working Examples 1-11 and the resinous sliding element in Comparative Examples 1-11 are distinguished by the presence or absence of embedded material, whereas all the other conditions are the same.

Commercial products A and B were prepared as the resinous sliding elements of Comparative Examples 12 and 13. Commercial product A in Comparative Example 12 comprised polyamide imide, graphite, and PTFE powder. Commercial product B in Comparative Example 13 comprised a phenol aralkyl resin, carbon fiber, and graphite.

The friction coefficients (μ) and relative abrasion amounts (mg/kg·mm) were measured using the resinous sliding elements of Working Examples 1-11 and Comparative Examples 1-13, and the stability of the friction coefficients was evaluated by a friction curve. The experiment conditions are shown below.

Device used in friction experiments: Mechanical Engineering Laboratory Type (Thrust Collar Type) Friction/Abrasion Tester.

Mating material: hollow cylinder of carbon steel (S45C), minor diameter 20 (mm), major diameter 25.6 (mm). Connecting edges wet-sanded with emery paper #500, surface roughness about 1 (mm Rz).

Test specimen: resinous sliding elements in above-mentioned Working Examples 1-11 and Comparative Examples 1-13 shaped into dimensions of $10 \times 40 \times 3$ (mm).

Load (kg), slipping velocity (m/s), slipping time (min): varied as shown in Table 1.

Atmosphere: no lubricant (dry), room temperature, atmospheric air.

Under the above-mentioned experiment conditions, the experiment was conducted after rotating the specimen and solidifying the mating material. In addition, the friction coefficient was the final value registered during the slipping time. Also, the relative abrasion amount is indicated as abrasion loss per unit load and sliding distance.

The experiment results are also shown in Table 1. However, the friction coefficient for the resinous sliding element in Comparative Example 4 was too high and could not be measured.

The resinous sliding elements in Working Examples 1 to 11 all show a lower value for the friction coefficient than those in Comparative Examples 1 to 11, in which the same matrix is used. The resinous sliding elements in Working Examples 1 to 11 have a friction coefficient of 0.17 or less, which is low compared with commercial products A and B in Comparative Examples 12 and 13. It is therefore clear that the resinous sliding elements in the present working examples have low friction compared with those in the comparative examples.

The resinous sliding elements in Working Examples 1, 2, 5, 6, 7, 8, and 10 (in which particularly hard matrices were used) have a low friction coefficient value of 0.10 or less. It is therefore clear that with the resinous sliding elements of the present working examples, lower friction is achieved when the matrix is endowed with increased hardness.

Table 1

Working Example Comparative Example No.	Resinous sliding element		Experiment conditions				Experiment results		
	Matrix (reinforcing material)	Presence of embedding material	Load, kg	Slipping velocity, m/S	Slipping time, min	PV, kg·m/cm^2·S	Friction coefficient, μ	Relative abrasion amount, mg/kg·mm	Stability of friction coefficient
Working Example 1	Nylon 66	yes	50	0.3	30	26	0.10	8.5×10^{-8}	O
Comparative Example 1		no	"	"	10	"	0.23	2.6×10^{-7}	×
Working Example 2	Nylon 66 (glass fiber)	yes	50	0.5	30	43	0.10	1.9×10^{-7}	Δ
Comparative Example 2		no	"	"	10	"	0.13	2.3×10^{-5}	×
Working Example 3	Polyoxymethylene	yes	15	0.4	22	10	0.17	5.4×10^{-8}	O
Comparative Example 3		no	"	"	20	"	0.27	7.9×10^{-8}	Δ
Working Example 4	Polyoxybenzoyl	yes	50	0.5	30	43	0.12	5.8×10^{-8}	Δ
Comparative Example 4		no	"	"	1	"	unmeasurable	2.8×10^{-5}	×
Working Example 5	Polyether ether ketone	yes	48	0.4	30	33	0.09	3.5×10^{-8}	O
Comparative Example 5		no	"	"	10	"	0.31	5.6×10^{-8}	×
Working Example 6	Polyamide imide (glass fiber)	yes	50	0.5	30	43	0.10	5.6×10^{-8}	O
Comparative Example 6		no	"	"	2	"	0.40	1.3×10^{-5}	×
Working Example 7	Polyimide	yes	50	0.8	30	69	0.10	6.9×10^{-8}	O
Comparative Example 7		no	"	0.5	15	43	0.24	1.7×10^{-6}	×
Working Example 8	Phenol aralkyl resin	yes	64	0.5	30	55	0.08	3.6×10^{-8}	O
Comparative Example 8		no	"	"	5	"	0.28	3.3×10^{-6}	×
Working Example 9	Phenol aralkyl resin (glass fiber)	yes	64	0.5	30	55	0.13	5.6×10^{-8}	O
Comparative Example 9		no	50	"	8	43	0.46	1.9×10^{-7}	×
Working Example 10	Rubber-modified phenol resin	yes	64	0.5	30	55	0.09	5.5×10^{-8}	O
Comparative Example 10		no	50	"	15	43	0.24	9.7×10^{-7}	Δ
Working Example 11	Rubber-modified phenol resin (glass fiber)	yes	64	0.5	30	55	0.14	7.1×10^{-8}	O
Comparative Example 11		no	50	"	6	43	0.38	4.2×10^{-7}	×
Comparative Example 12	Commercial product A	-	48	0.4	20	33	0.27	2.1×10^{-7}	Δ
Comparative Example 13	Commercial product B	-	50	0.5	10	43	0.40	2.4×10^{-7}	×

The friction curve of the resinous sliding elements in Working Example 8 and Comparative Example 8 is shown in Fig. 3 and Fig. 4. It is clear from Table 1, Fig. 3, and Fig. 4 that while the resinous sliding element in Working Example 8 displays a remarkably stable friction coefficient, the sliding element of Comparative Example 8 displays a widely fluctuating friction coefficient. The resinous sliding elements in the other working examples also display a stable friction coefficient, while those of the other comparative examples also display a widely fluctuating friction coefficient. It is therefore clear that with the PV ($kg \cdot m/cm^2 \cdot s$) values shown in Table 1, the resinous sliding elements in the working examples have stable low friction under high-load conditions in comparison with those in the comparative examples.

Furthermore, an analysis of the relative abrasion in, for example, the resinous sliding elements of Working Example 8 and Comparative Example 8 indicates that while the resinous sliding element in Comparative Example 8 has an abrasion on the order of 10^{-6}, that of Working Example 8 is on the order of 10^{-8}, which is lower than that of Comparative Example 8 by two orders of magnitude, as shown in Table 1. The resinous sliding elements of the other working examples are also lower than those of the comparative examples by one to two orders of magnitude. It is therefore clear that the resinous sliding elements of the present working examples display relative abrasion amounts that are superior to those in the comparative examples.

In addition, while the resinous sliding elements reinforced by glass fiber in Comparative Examples 2, 6, 9, and 11 produced considerable damage in the mating material, those reinforced by glass fiber in Working Examples 2, 6, 9, and 11 mostly did not damage the mating material. It is therefore clear that the resinous sliding elements of the present working examples do not easily damage the mating material even when mechanical strength has been improved.

From evaluating the above-mentioned friction coefficients, relative abrasion amounts, and stability of friction coefficients, it is clear that the resinous sliding elements with embedded materials in Working Examples 1 to 11 have lower friction and abrasion resistance at high PV values than the matrix-only resinous sliding elements and the commercial products in Comparative Examples 1 to 13.

(Experiment 2)

Comparative testing was performed on the friction curves of the resinous sliding elements in the working examples (wherein PTFE had been embedded in bulk form) and of those in the comparative examples (wherein PTFE had been dispersed in the form of powder).

For Working Example 12, an embedded material comprising PTFE in the form of rods with a thickness of 1 mm and an area ratio of 12% was embedded in the same matrix as in the above-mentioned Comparative Example 9, yielding a resinous sliding element.

For Comparative Example 14, a resinous sliding element was obtained by dispersing 25 wt% of PTFE powder with a particle size of 1 to 10 μm into the same matrix as in Working Example 9, and mixing and molding the resulting product.

The friction curves in the above-mentioned Working Example 9, Working Example 12, and Comparative Example 14 were measured. The PV value in Working Example 9, Working Example 12, and Comparative Example 14 was 30 (kg·m/cm^2·s), and the other conditions were the same as in Experiment 1.

The friction curves for the resinous sliding elements in Working Examples 9 and 12 are shown in Fig. 5 and Fig. 6, and the friction curve for the resinous sliding element in Comparative Example 14 is shown in Fig. 7.

It is clear from Figs. 5-7 that while the resinous sliding elements in Working Examples 9 and 12 display a remarkably stable friction coefficient, the sliding element of Comparative Example 14 displays a widely fluctuating friction coefficient. It is therefore clear that the resinous sliding elements in the present working examples have stable low friction under high-load conditions compared with conventional examples wherein PTFE powder has been dispersed.

(Experiment 3)

Comparative testing was conducted using various matrix resins for the resinous sliding elements in the working examples (wherein PTFE had been embedded in bulk form) and for those in the conventional examples (wherein PTFE had been dispersed in the form of powder). The bulk PTFE used as the embedded material was in the form of rods with a thickness of 0.5 to 1 (mm) and an area ratio of 20%. The powder PTFE had an average particle size of 10 (μm), and the fiber PTFE had a length of about 10 (mm) and a thickness of 50 (μm) or less. The glass fiber used as the reinforcing material dispersed in the matrix was the same as in Experiment 1.

For Working Example 13, a resinous sliding element was manufactured by pressing an embedded material comprising the above-mentioned bulk PTFE into the matrix (plate-shaped nylon 66) by thermal compression.

For Comparative Example 15, a resinous sliding element was manufactured by dispersing the above-mentioned fiber PTFE in the matrix (powdered nylon 6) at a content of 20 wt%, and mixing and thermocompression-molding the resulting product.

For Comparative Example 16, a resinous sliding element was manufactured by dispersing the above-mentioned fiber PTFE into the matrix (powdered nylon 6) at a content of 25 wt%, and mixing and thermocompression-molding the resulting product.

For Comparative Example 17, a resinous sliding element was manufactured by thermocompression-molding powdered nylon 6 alone.

Similarly, as shown in Table 2, the resinous sliding elements in Working Examples 14 to 17 and Comparative Examples 18 to 28 were manufactured with varying types of matrices and varying forms of PTFE. In addition, the resinous sliding element in Working Example 17 was obtained by embedding an embedded material into a plate-shaped matrix by thermal compression in the same manner as in Working Example 13, and the resinous sliding elements of Working Examples 14 to 16 and Comparative Examples 18 to 28 were obtained by thermocompression molding using powdered resins.

The friction coefficients and relative abrasion amounts were measured using the resinous sliding elements of Working Examples 13 to 17 and Comparative Examples 15 to 28, and the stability of the friction coefficients was evaluated by the friction curves. The experiment conditions were mostly the same as in Experiment 1, as is shown in Table 2.

The experiment results are also shown in Table 2. The friction curves for the resinous sliding elements in Working Examples 13 to 16 and Comparative Examples 15, 16, 18, 19, 21, 22, 24, and 25 are shown in Figs. 8 to 20. In some of the diagrams, a temperature curve is also shown by a dotted line. Fig. 9 and Fig. 10 relate to the resinous sliding element in Comparative Example 15, but the PV is 26 ($kg \cdot m/cm^2 \cdot s$) in Fig. 9, and 21 ($kg \cdot m/cm^2 \cdot s$) in Fig. 10. The working examples and comparative examples are evaluated below, with identical matrix resins being used in these examples.

Table 2

	Resinous Sliding Element		Experiment Conditions				Experiment Results		
Working Example Comparative Example	Matrix (reinforcing material)	Form of PTFE	Load, kg	Slipping velocity, m/S	Slipping time, min	PV, kg·m/cm^2·S	Friction coefficient, μ	Relative abrasion amount, mg/kg·mm	Stability of friction coefficient
Working Example 13	Nylon 6	Bulk (area ratio 20%)	50	0.3	30	26	0.12	7.7×10^{-8}	O
Comparative Example 15		Fiber (content ratio 20 wt%)	"	"	5	"	0.20-0.27	1.9×10^{-6}	×
Comparative Example 16		Powder (" 25 wt%)	"	"	30	"	0.13	2.7×10^{-8}	Δ
Comparative Example 17		None	"	"	20	"	0.20	3.7×10^{-7}	Δ
Working Example 14	Phenol aralkyl resin	Bulk (area ratio 20%)	45	0.5	30	39	0.09	7.4×10^{-8}	O
Comparative Example 18		Fiber (content ratio 20 wt%)	"	"	20	"	0.25-0.29	2.3×10^{-7}	×
Comparative Example 19		Powder (" 25 wt%)	"	"	"	"	0.13	7.3×10^{-8}	Δ
Comparative Example 20		None	"	"	6	"	0.33 or greater	1.5×10^{-6}	×
Working Example 15	Phenol aralkyl resin (glass fiber)	Bulk (area ratio 20%)	45	0.5	30	39	0.14-0.17	6.6×10^{-8}	Δ
Comparative Example 21		Fiber (content ratio 20 wt%)	"	"	"	"	0.11-0.17	9.2×10^{-8}	×
Comparative Example 22		Powder (" 25 wt%)	"	"	"	"	0.12-0.13	4.4×10^{-8}	Δ
Comparative Example 23		None	"	"	5	"	0.33 or greater	3.5×10^{-7}	×
Working Example 16	Polyimide	Bulk (area ratio 20%)	100	0.5	30	86	0.08	5.0×10^{-8}	O
Comparative Example 24		Fiber (content ratio 20 wt%)	45	"	11	39	0.29-0.33	1.8×10^{-7}	×
Comparative Example 25		Powder (" 25 wt%)	"	"	16	"	0.27	5.0×10^{-8}	×
Comparative Example 26		None	"	"	25	"	0.16-0.27	4.7×10^{-7}	×
Working Example 17	Polyether ether ketone	Bulk (area ratio 20%)	50	0.5	30	43	0.11	3.5×10^{-8}	O
Comparative Example 27		Powder (" 25 wt%)	45	"	"	39	0.18	1.8×10^{-8}	Δ
Comparative Example 28		None	48	0.4	10	33	0.33	5.4×10^{-6}	×

Note: there is no page 13

1. Comparison of resinous sliding elements in Working Example 13 and Comparative Examples 15-17 (see Fig. 2 and Figs. 8-11)

"Friction Coefficient:" The resinous sliding elements in Working Example 13 (wherein a bulk PTFE is embedded) and Comparative Example 16 (wherein powdered PTFE is dispersed) have nearly identical low friction coefficients, but the former displays a more stable friction coefficient compared with the latter. The resinous sliding elements in Comparative Example 15 (wherein fiber PTFE is dispersed) and Comparative Example 17 (comprising only a matrix) have high, widely fluctuating friction coefficients.

"Relative Abrasion Amount:" The resinous sliding elements in Working Example 13 and Comparative Example 16 have relative abrasion amounts that are of nearly the same order of magnitude, but the former has a relative abrasion amount of about 2 to 3 times that of the latter. The resinous sliding elements in Comparative Example 15 and 17 have relative abrasion amounts greater than those in Working Example 13 and Comparative Example 16 by about one to two orders of magnitude.

2. Comparison of resinous sliding elements in Working Example 14 and Comparative Example 18-20 (see Table 2 and Figs. 12–14)

"Friction Coefficient:" The resinous sliding element in Working Example 14 (wherein a bulk PTFE is embedded) displays a friction coefficient of 0.1 or less, which is a far lower value compared with those in Comparative Examples 18 to 20. The resinous sliding element in Working Example 14 displays a far more stable friction coefficient compared with those in Comparative Example 18 to 20.

"Relative Abrasion Amount:" The resinous sliding element in Working Example 14 has nearly the same relative abrasion amount as that in Comparative Example 19 (wherein powdered PTFE is dispersed).

3. Comparison of resinous sliding elements in Working Example 15 and Comparative Example 21-23 (see Table 2 and Figs. 15-17)

"Friction Coefficient:" With the exception of the sliding element in Comparative Example 23 (in which a matrix alone is used), the resinous sliding element in Working Example 15 (wherein bulk PTFE is embedded) displays a rather high friction coefficient, which is also more stable than the friction coefficients in Comparative Examples 21 and 22.

"Relative Abrasion Amount:" The resinous sliding element in Working Example 15 has nearly the same relative abrasion amount as those in Comparative Examples 21 and 22, and the damage to the mating surface is less pronounced.

4. Comparison of resinous sliding elements in Working Example 16 and Comparative Examples 24-26 (see Table 2 and Figs. 18-20)

"Friction Coefficient:" The resinous sliding element in Working Example 16 (wherein bulk PTFE is embedded) has a very low and stable friction coefficient despite the fact that the coefficient was measured at a higher PV value than in Comparative Examples 24 through 26.

"Relative Abrasion Amount:" The resinous sliding element in Working Example 16 has an identical relative abrasion amount to that in Comparative Example 25.

5. Comparison of resinous sliding elements in Working Example 17 and Comparative Examples 27 and 28 (see Table 2)

"Friction Coefficient:" Similar to the sliding element of Working Example 16 the resinous sliding element in Working Example 17 (wherein bulk PTFE is embedded) has a low, stable friction coefficient despite the fact that the coefficient was measured at a higher PV value than in Comparative Examples 27 and 28.

"Relative Abrasion Amount:" The resinous sliding element in Working Example 17 has a relative abrasion amount about two times that of Comparative Example 27.

It is clear from the evaluations described above that the resinous sliding elements of the present working examples (wherein PTFE is embedded in bulk form) display abrasion resistance and stable low friction under high-load conditions compared with conventional examples (wherein PTFE is dispersed in fiber or powder form or is absent altogether), and the emission of heat can be suppressed due to low friction.

It is therefore clear from Experiments 1 through 3 that the resinous sliding elements of the present working examples can be provided as materials having high limiting PV values and excellent sliding properties.

(Experiment 4)

A test was conducted to determine the area ratio (%) in which the embedded material should be embedded in the sliding surface to make the product effective as a sliding resin element. The experiment conditions are shown below.

Test specimen: An embedded material in rod form comprising PTFE in a linear or radial pattern with a thickness of about 1 (mm), embedded at various area ratios (%) across a circular sliding surface that measured 50 (diameter) × 3 (mm) and comprised 70 wt% of a phenol aralkyl resin as a matrix and 30 wt% of glass fiber (same as in Experiment 1).

Load, sliding velocity: load 88 (kg (surface pressure 44 kg/cm^2)), sliding velocity 0.6 (m/s). Therefore, PV = 26 (kg·m/cm^2·s).

The other conditions were the same as in (Experiment 1).

The relationship between the area ratio and friction coefficient is shown in Fig. 21, and the relationship between the area ratio and relative abrasion amount is shown in Fig. 22.

It is clear from Fig. 21 and Fig. 22 that the friction coefficient is 0.33 and the relative abrasion amount is 6.5×10^{-7} (mg/kgf·mm) when the area ratio of the embedded material is 0 (specifically, in the case of the matrix itself), whereas the friction coefficient and relative abrasion amount decrease when the area ratio of the embedded material is about 3% or greater. The friction coefficient decreases together with the increase in the area ratio, and the friction coefficient decreases to 0.10 or less when the area ratio is about 10% or greater. Conversely, the once decreased value of the relative abrasion amount displays a tendency to increase somewhat with an increase in the area ratio. It is therefore clear that the embedded material should be embedded at an area ratio of 5 to 40% in relation to the sliding surface of the matrix.

(Effect of the Invention)

As described in detail above, the resinous sliding element of the present invention comprises an embedded material made of a fluororesin embedded in the sliding surface of a matrix at an area ratio of 5 to 40% and exposed in the form of rods or a mesh, and therefore has low friction and excellent abrasion resistance even under high-load conditions. The resinous sliding element also does no easily damage the mating surface when its mechanical strength has been improved.

4. Brief Description of the Drawings

Fig. 1 is a perspective view of the resinous sliding element in Working Example 1, and Fig. 2 is an enlarged cross-sectional view of the resinous sliding element in Working Example 1.

Figs. 3 through 7 show friction curves for the resinous sliding elements, where Fig. 3 is a graph of Working Example 8, Fig. 4 is a graph of Comparative Example 8, Fig. 5 is a graph of Working Example 9, Fig. 6 is a graph of Working Example 12, and Fig. 7 is a graph of Working Example 14. Figs. 8 to 20 show friction curves for the resinous sliding elements, where Fig. 8 is a graph of Working Example 13, Fig. 9 and Fig. 10 are graphs of Comparative Example 15, Fig. 11 is a graph of Comparative Example 16, Fig. 12 is a graph of Working Example 14, Fig. 13 is a graph of Comparative Example 18, Fig. 14 is a graph of Comparative Example 19, Fig. 15 is a graph of Working Example 15, Fig. 16 is a graph of Comparative Example 21, Fig. 17 is a graph of Comparative Example 22, Fig. 18 is a graph of Working Example 16, Fig. 19 is a graph of Comparative Example 24, and Fig. 20 is a graph of Comparative Example 25. Fig. 21 is a graph showing the relationship between the area ratio and friction coefficient, and Fig. 22 is a graph showing the relationship between the area ratio and relative abrasion amount.

1: matrix 2: embedded material

Patent Applicant: Toyota Central R&D Labs., Inc.

Agent: Hiroshi Okawa, Patent Attorney

Fig. 1

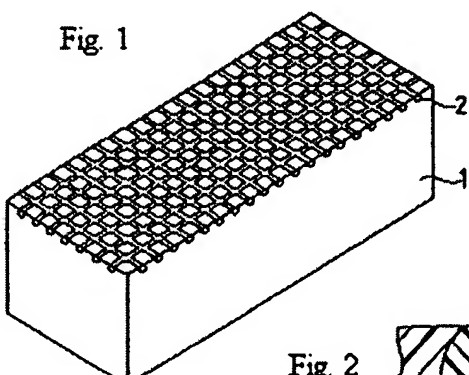

Fig. 2

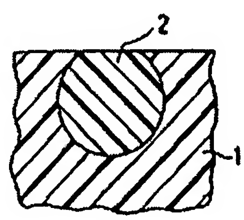

Fig. 3

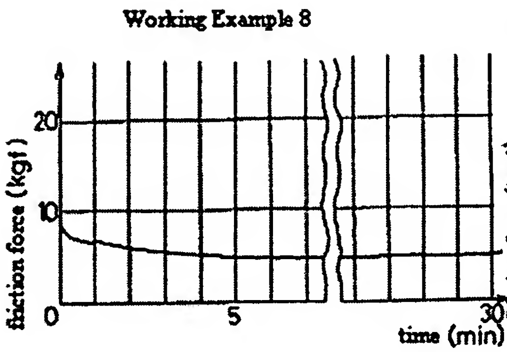

Fig. 4

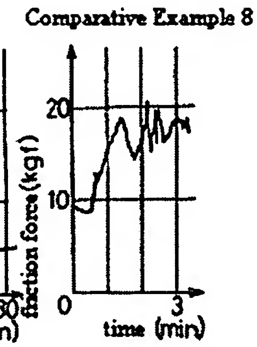

Fig. 5

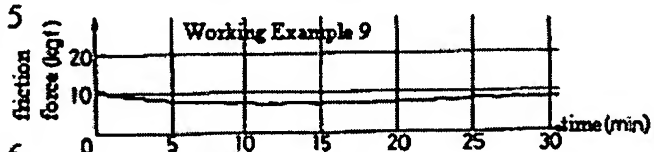

Fig. 6

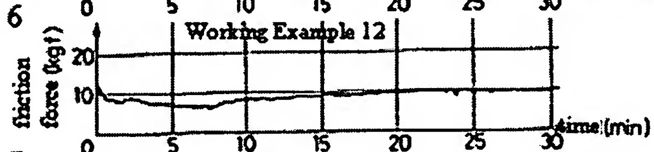

Fig. 7

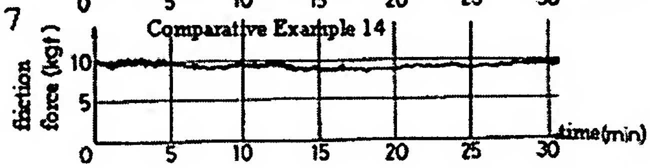

Fig. 8

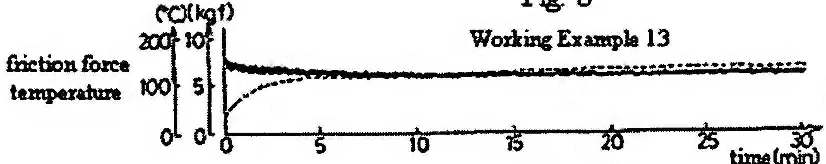

Fig. 10

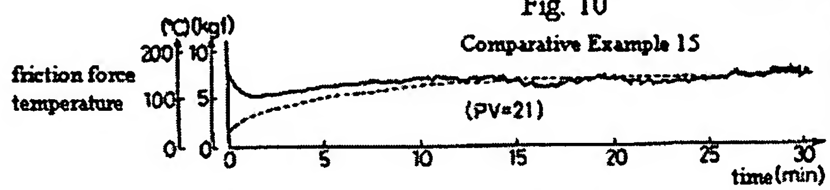

Fig. 11

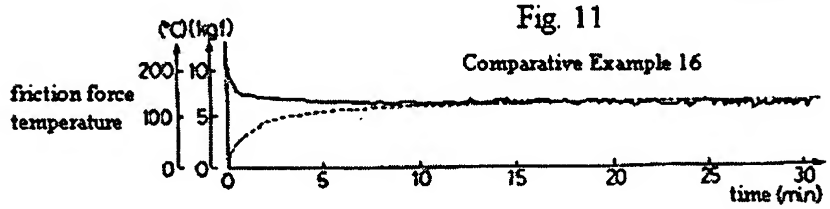

Fig. 9

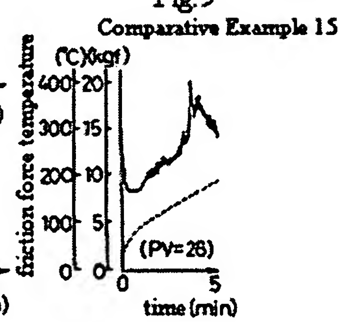

Fig. 18

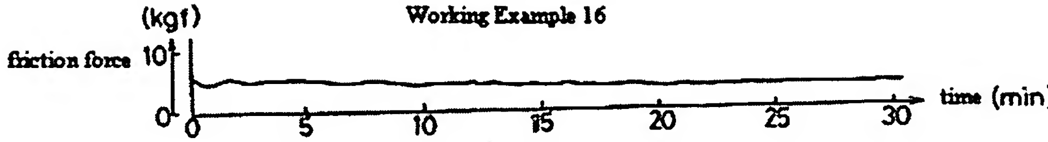

Fig. 19

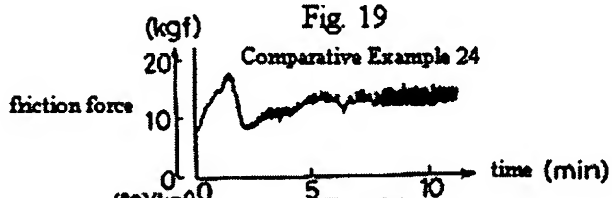

Fig. 20

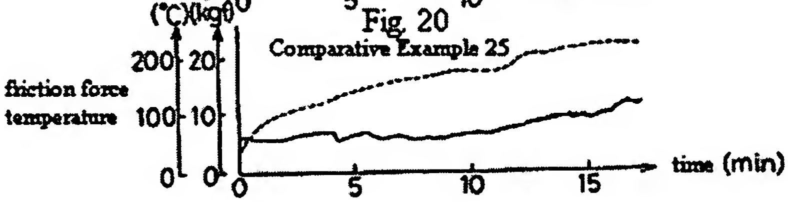

Fig. 21

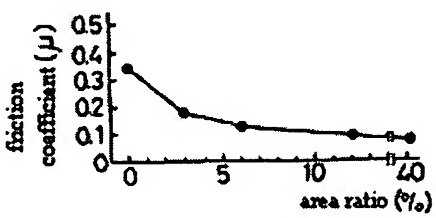

Fig. 22